John Moisan and Jeffrey Hosler

NASA Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, VA 23337

Introduction

As the hurricane season of 2005 clearly showed, predicting the path of tropical storms can be tricky. Inaccurate data can throw off a forecast by miles. Because it costs a community about $1 million a mile to evacuate its residents and visitors, knowing more precisely where a hurricane will make landfall could save hundreds of millions of dollars and allow rescue personnel to concentrate their resources on the hardest-hit areas [1].

The solution lies in creating a more reliable method of gathering *in situ* measurements of ocean surface winds, air temperatures, water salinity, and currents—factors that influence Atlantic storms. Unfortunately, gathering information on the open ocean presents big challenges and risks to scientists. As a result, while tens of thousands of observations are taken on land, only hundreds are taken on the ocean.

Part of the problem lies with the tools used to gather this all-important data, which are fed into supercomputers that then analyze the information and predict a hurricane's intensity and direction. The most commonly used techniques today include stationary or drifting buoys, research ships, and remotely sensed data collected by satellites, aircraft, and low-cost sensor packages. However, none is perfect for finding out conditions on the open seas.

For example, buoys that drift with the currents are short-lived and cannot be recovered, and those that are anchored to one spot are expensive to deploy, maintain, and redeploy—requiring a large number of people and vessels for the task. Research ships can cost from a few thousand dollars a day for coastal monitoring to $15,000 or more for ocean-class surveillance. Add up the numbers and this solution quickly becomes cost prohibitive.

Although satellites offer the advantage of gathering a larger amount of data, they often carry sensors that cannot see through clouds—a significant obstacle when dealing with hurricanes and other weather-related phenomena.

Given the physical and technical difficulties now hampering efforts to collect more precise and timely data, the National Aeronautics and Space Administration (NASA) joined forces with the National Oceanic and Atmospheric Administration (NOAA) to create a new system for collecting *in situ* ocean data using an autonomous ocean vessel. Recent demonstrations have proven the promise of these developing technologies.

Ocean–Atmosphere Sensor Integration System (OASIS)

At the heart of the research and development program is the Ocean–Atmosphere Sensor Integration System (OASIS) platform, a low-cost, self-navigating platform developed at the Wallops Flight Facility in Virginia, with significant funding from NOAA.

As designed by NASA, scientists would equip these unmanned surface vehicles with a range of instruments and sensors and deploy them from land or from small research vessels operating along coastal waters. The solar-powered platforms would travel at speeds of up to 2.5 knots (the speed of the fastest ocean currents and 10 times the average speed for ocean currents) to the targeted destination. Upon arrival at their destination, they would carry out their measurements, transmit and receive data by way of their real-time, two-way, Iridium satellite-based communication systems, and then return to their home base for refurbishment and calibration once they completed their observations. The hull of the vessel was specifically designed to survive hurricane conditions.

Currently, a commercial version of the platform is being developed to allow for rapid fabrication of a small fleet. Developers of the platforms at NASA purposely used off-the-shelf parts to keep down costs, and the platforms are likely to be available for about $80,000 for low fabrication numbers.

Adaptive Sensor Fleet (ASF)

Although the OASIS platforms can operate independently, software engineers at the Goddard Space Flight Center in Greenbelt, MD, have developed a technology that is ideal for controlling them.

The Adaptive Sensor Fleet (ASF) is a measurement software system that can guide fleets of data-gathering platforms—such as OASIS—as well as Mars-type rovers and eventually, unmanned aircraft to areas where scientists need up-to-the-minute information about local environmental conditions. With ASF, scientists define what they want to observe and the measurements they want to gather; the system analyzes the mission and recommends the best arrangement of platforms to carry out the task. The system's "fleet manager" then divides the work among the different ASF-equipped platforms, ideally using all platforms in the fleet to handle the mission.

Throughout the operation, the system communicates with the platforms, sends commands to the individual instruments and sensors in the fleet, and receives *in situ* measurements from the platform instruments. Scientists simply monitor the platforms' progress as they travel to the site and began gathering data. In other words, they have little or no interaction with the system once they input their mission requirements.

At a recent demonstration at the Goddard Space Flight Center, ASF designers used three small robots operating in a simulated Martian landscape to show the technology's capabilities. After programming target and data requirements into the system, the inventors watched as the fleet manager took charge. It distributed data-gathering assignments, determined the routes, and modified instructions if the rovers encountered obstacles. As the robots advanced to their target, the software system displayed the rovers' progress and their cumulative scientific data on a computer screen.

Ideal for Meteorological Purposes

Although ASF team members demonstrated the technology on a simulated Martian surface to show its applicability to space exploration, they believe the technology has wider use on Earth in the near term—particularly in the area of ocean studies.

Used in conjunction with other measurement assets, including satellites, ASF-equipped OASIS platforms could gather more precise, up-to-the-minute ocean surface and subsurface data needed for hurricane forecasting models. The availability of more data would make a significant difference. Because of measurement inaccuracies and too few observations, meteorologists now consider a good forecast to be one that gets the location of a hurricane to within 50 miles and wind speeds to within 8 mph, 12 hours before the storm makes landfall [2]. When evacuating citizens, however, 50 miles is a large area to cover. Because OASIS is fully autonomous, unlike the traditional fixed buoys that are logistically demanding to move and drifters whose paths cannot be controlled, it can be redeployed easily to carry out observations in other ocean regions and all from a desktop computer.

Other Applications

The technologies have other applications, too. In addition to sending the platforms to study hurricanes, environmental organizations could use ASF-equipped OASIS platforms to monitor the health of important coastal areas. In fact, such a demonstration is scheduled to occur along the coasts of Virginia, Maryland, and Delaware. There, researchers hope to monitor the influence of the Chesapeake Bay and adjacent coastal ecosystems. A NASA-funded effort with Carnegie Mellon University is now underway to use OASIS platforms to map and monitor harmful algal blooms.

The Future

The creators of both OASIS and ASF say they will continue to fine-tune their technologies and demonstrate their usefulness under different research environments. Used together or separately, ASF and OASIS could help scientists with everything from tracking killer storms and algal blooms on Earth to navigating rovers on the Moon or Mars.

Acknowledgments

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Additional Reading

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Web Sites

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Biographical Sketches

John Moisan: Dr. Moisan received a B.S. in Marine Biology from the University of New England and a Ph.D. in Physical Oceanography from Old Dominion University. Before coming to NASA in 2000, he was employed as a post-doc at the Scripps Institution of Oceanography and also as an Assistant Professor at Long Island University. His research focus is on developing coupled circulation-biogeochemical models and in developing new sensors for studying the ocean autonomously.

Jeffrey Hosler: Mr. Hosler received a B.S. in Computer Science with Aviation Applications from Embry-Riddle Aeronautical University. Over the past six years, as a software R&D manager at the Goddard Space Flight Center in Greenbelt, MD, he has

Glossary

Autonomous—operating independently or alone.

Buoy—an anchored float equipped with scientific instruments and sensors.

Fabrication—the act of constructing something from raw materials.

In situ—Latin phrase meaning “in its original place.”

Knot—a unit of measurement for the speed at which a ship or aircraft travels (nautical miles per hour).

Meteorologists—people who study Earth’s climate and weather.

Sensors—devices capable of detecting physical conditions, such as light and heat.

Salinity—the amount of salt in a body of water.

explored cutting-edge technologies in distributed architectures, sensor webs, fleet control, path planning, agent-based systems, and Web technologies. Goddard has incorporated the research into its Mission Services Evolution Center and used it as the basis for other research.